THE STATUS OF FOREST BIODIVERSITY IN NORTH AMERICA

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SZARO, R.C. 1992. The status of forest biodiversity in North America. Even in North America with the intensity of scientific effort focused on natural resources, it is extremely difficult to assess the overall status of forest biodiversity. Rarely have studies been done examining all the vascular plants and vertebrates and their relationship in any given ecosystem, let alone the thousands of other species found in any given system. Better inventories and assessments are needed of current conditions, abundances, distribution, and management direction for genetic resources, species population, biological communities and ecological systems. Changes monitored over time allow us to assess the consequences of management practices. It is essential in an adaptive management strategy that one be capable of monitoring critical indicators of diversity, particularly those related to management objectives,and those variables that can be used to explain behaviour and predict future trends. Approaches must be developed and implemented for the preservation, maintenance, restoration, and sustainable use of forest ecosystems. Maintaining biodiversity requires attention to a wider array of components in determining management options as well as the management of larger landscape units. There will be trades-offs, commodity production may decline in the short term, but in the long term these trade-offs will result in gains in sustained productivity while maintaining biodiversity with its complete range of ecological processes.

Key words: Biodiversity - forest ecosystem - North America - sustainability - restoration - status

SZARO, R.C. 1992. Status biodiversiti di Amerika Utara. Walaupun dengan adanya usaha-usaha saintifik yang tertumpu kepada sumber asli, masih lagi sukar untuk menilai status keseluruhan biodiversiti hutan di Amerika Utara. Amat jarang kajian dijalankan untuk meneliti semua tumbuhan vaskular dan vertebrata dan perhubungan mereka di sesuatu ekosistem, apatah lagi beribu-ribu spesies yang terdapat di sesuatu sistem. Penaksiran dan inventori yang lebih baik mengenai keadaan semasa, kekayaan, taburan dan arah pengurusan sumber genetik, populasi spesies, komuniti biologi dan sistem-sistem ekologi adalah diperlukan. Perubahan-perubahan yang dikesan mengikut masa untuk mentaksir kesan amalan-amalan pengurusan adalah penting dalam strategi pengurusan adaptif, yang membolehkan seseorang itu berkeupayaan mengawas petunjuk kritikal kepelbagaian terutama yang berkaitan objektif pergurusan dan angkubah-angkubah yang boleh digunakan untuk menerangkan geraklaku dan meramal kecenderungan masa hadapan. Pendekatan-pendekatan hendaklah dimajukan dan dilaksanakan untuk memelihara, menyelenggara, memulih dan menggunakan ekosistem hutan dengan berkekalan. Memelihara biodiversiti memerlukan perhatian diberi kepada komponen-komponen lain yang lebih luas dalam menentukan pilihan pengurusan dan juga pengurusan unit-unit landskap yang lebih besar. Pasti perlu ada tolak ansur, keluaran komoniti mungkin menurun dalam jangkamasa pendek tetapi dalam jangkamasa panjang tolak ansur ini akan menghasilkan keuntungan dalam produktiviti berkekalan disamping memelihara biodiversiti dan semua proses ekologinya.

Introduction

Biodiversity and its conservation and sustainable use is an issue that has recently been embroiled in heated debate because of the confusion and disagreement over what it is, how to measure accomplishment, and what kinds of measures are needed to maintain future resource options. It may be difficult to come up with a precise textbook definition, but there is no real mystery about it. What is biodiversity? Perhaps the simplest and, at the same time, most complete definition of biodiversity as formulated in the Keystone Biodiversity Dialogue Report (Keystone Centre 1991) is that "Biodiversity is the variety of life and its processes". The recently negotiated global Convention on Biological Diversity defined it as follows:

"Biological diversity" means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species and of ecosystems.

Clearly every effort should be made to conserve biodiversity (Evans & Szaro 1990, Szaro 1990, Szaro 1992 a,b) The conservation of biodiversity encompasses genetic diversity of species populations, richness of species in biological communities, processes whereby species interact with one another and with physical attributes within ecological systems, and the abundances of species, communities and ecosystems at large geographic scale (Harrington *et al.* 1990). In recent years, traditional uses of forested lands in North America have become increasingly controversial (Szaro & Shapiro 1990). The demands and expectations placed on these resources are high and widely varied, calling for new approaches that go beyond merely reacting to resource crises and concerns (Szaro 1990, Szaro & Salwasser 1991).

But how can land managers react to the oftentimes painful dilemmas they face on an almost daily basis when making management decisions that can have potentially devastating impacts on forest stability? The disclipine of Conservation Biology has been described as a "crisis discipline, where limited information is applied in an uncertain environment to make urgent decisions with sometimes irrevocable consequences" (Maquire 1991). This really speaks to the heart of all land managers. They find themselves trying to find the balance between maintaining and sustaining forest systems while still providing the forest products needed by people. Trade-offs will be inevitable and will necessitate formulating and using alternative land management strategies to provide an acceptable mix of commodity production, amenity use , protection of environmental and ecological values, and biodiversity. Conserving biodiversity now is likely to alter immediate access to resources currently in demand in exchange for increasing the likelihood that long-term productivity, availability and access are assured.

Is this dilemma something new? Are we the first to wrestle with these kind of decisions? With massive simplification of landscapes? Plato in approximately 2350 B.C. describes an area in ancient Greece that was stripped of soil following clearing and grazing (Formann 1987). In fact, since the development of agriculture, there have been extensive modifications to the natural vegetations cover of every continent except Antartica (Saunders *et al.* 1991). Yet, never before have there been so many humans on earth taking advantage of its resources.

It is hardly surprising then, that global awareness and concerns for conserving biodiversity are continually increasing. When we have concerns for biodiversity we are saying we have a concern for all life and its relationships (Szaro 1992a). As arguably the most intelligent species on earth we have a responsibility to try as much as possible for the continuance of all forms of life. But how can we go about this? The first step is trying to determine the amount, variety, and distribution of species, ecosystems, and landscapes. This will require more comprehensive inventories which must be followed by monitoring efforts to determine the impacts of management activities. Next, strategies must be developed and implemented for the preservation, maintenance, and restoration of forest ecosystems. These efforts should also incorporate strategies for the sustainable use of forest resources including more efficient utilization, recycling programmes, and forest plantations in order to meet human needs.

Status of forest ecosystems and timber resources

Even in North America with the intensity of scientific effort focussed on natural resources, it is extremely difficult to assess the overall status of forest biodiversity. Many exhaustive studies have been done on the attributes of particular forest ecosystems, their associated animal faunas and their distribution across the landscape. Nevertheless, much of this information is fragmented, disorganised, and hardly comprehensive. Rarely have studies been done examining all vascular plants and vertebrates and their relationship in any given ecosystem, let alone the thousands of other species found. Forest area in North America varies from a high of 45% in Canada to a low of 29% in Mexico (Table 1). Canada, the United States, and Mexico all have some type of forest inventory. However, all have primarily been directed at determining volume of timber, predominant genera, and to varying degrees forest types or ecosystems. There are many problems in comparing data between the three countries including differing definitions for forest land, scales of resolution, and methods of access to available but oftentimes unpublished information. These problems are further exacerbated by the fact that there is no agreed-upon ecosystem classification that could serve for the forest biodiversity in the continent as a whole. As a result data on forest biodiversity is artificially fragmented into sections based on political boundaries that obviously would not be a first choice in organising any information on North American forest biodiversity, but are an unfortunate necessity.

Canada

The boreal forest formation of North America is a continuous vegetation belt stretching across the continent from the Atlantic shoreline of central Labrador across Canada to the mountains and interior and central coastal plains of Alaska that encompasses a large portion of Canada's forests (Elliot-Fisk 1988). Even though the boreal forest formation is often depicted as a monotonous coniferous forest of uniform composition and physiognomy, it is in reality a complex mosaic of different plant communities principally dominated by coniferous trees (Elliot-Fisk 1988). In the more than two million hectares of this zone in Canada 38 species of trees are found (Boyle 1992). Overall,the composition of Canada's forests is predominantly coniferous or mixed conifer and hardwood complexes (Forestry Canada 1988). Canada has several other forest formations with an increasing gradient in species diversity from north to south with exceptional areas of diversity in southern and western British Columbia (Boyle 1992).

Table 1. Forest resources in North America (100,000 *ha*)

Country	Total land & water area	Forest area	Percent total area
Canada[1]	9,971	4,533	45
United States[2]	9,570	2,960	31
Mexico[3]	1,973	564	29
Total	21,514	8,057	105

[1] Data from Canada's Forest Inventory 1986 (Forestry Canada 1988); [2] Data from 1987 Resources Planning Act data base (USDA Forest Service 1989); [3] Data from Cedillo (1990)

Of Canada's 997 million *ha* about 453 million *ha* (Table 1) are classified as forest land (Forestry Canada 1988). Of this forested land only 244 million *ha* (54%) is classified as land that is capable of producing a forest crop. Forests have historically been perceived in Canada as in most other countries of the world in terms of their commercial value (Forestry Canada 1992). However, in recent years, biodiversity has assumed a prominent place on the Canadian public agenda. Canada's forest inventory has used broad forest type categories of softwood (136.9 million *ha*), mixedwood (49.8 million *ha*), and hardwood (31.3 million *ha*), further broken down by predominant genus (Table 2, Forestry Canada 1988).

United States

The United states has lost forest land and biodiversity since colonial times (SAF 1991). Large areas of natural ecosystems have been converted for agriculture, residences and transportation corridors (Williams 1989). Species have gone extinct and the list of endangered species continues to grow. Pollution has degraded many remaining natural ecosystems. Since European settlement (nearly 400 years ago), the forest area of United States has declined by about 30%. Forest land area in the United States has declined from an estimated 385 million *ha* at the time of initial European settlement to as little as 245 million *ha* in the early 1900s.

Table 2. Productive forest land area (100,000 *ha*) by forest composition in Canada[1]

		Forest types	
Predominant genus	Softwood	Mixed wood	Hardwood
Softwood:			
Spruce	360	55	<1
Pine	313	49	<1
Fir	91	19	1
Hemlock	43	2	<1
Douglas Fir	42	2	-
Larch	7	<1	<1
Cedar & other conifers	30	6	<1
Unspecified conifers	77	<1	-
Hardwood:			
Poplar	<1	90	110
Birch	1	35	25
Maple	<1	9	40
Other broadleaf	<1	3	8
Unspecified broadleaf	-	24	79
Unclassified	405	203	49
Total	1369	498	313

[1]Data from Canada's Forest Inventory 1986 (Forestry Canada 1988)

Forest area increased from that low point as idle and abandoned cropland reverted to forest, a process that was reversed in the 1950s. In the past 30 to 40 years forest area declined as forests were cleared for agriculture production (primarily in the south) and forests were cleared for urban and other uses in all regions. In the past decade, the decline in total forest area in the United States may have been halted. Weaker markets for agriculture commodities reduced conversion of forest to crop and pasture land, and programmes to increase afforestation of idle and marginal crop land (such as the Conservation Reserve Programme) appear to have offset losses of forest to housing and urban development.

In 1987, 31% of the total land base in the United States was in forest (Table 3, USDA Forest Service 1989). Approximately 7% of the world's forests are in the United States, amounting to nearly 300 million *ha*; 67% of this land is privately owned and managed. Roughly 210 million *ha* of the country's forests are classified as timberland (capable of producing crops of industrial wood.);more than 90% of this area is available for timber production and management. Less than 10% of the current forest area of the United States has been undisturbed by human use or management.

The long-term trend in forest cover for the United States is a decline. Short-term cycles around this trend have been the result of significant shifts in agricultural production (the most notable being the period of farm abandonment, 1930-50). Major factors contributing to the long-term decline in forest cover (population and income growth) are expected to continue. Current demands for forest products have brought about the wide spread clear-cutting of natural,unevenaged stands and their replacement with even-aged, often monocultural, stands (Robinson 1988). Recent shifts away from clear cutting in National Forests and the implementation of a ecosystem management philosophy by the USDA Forest Service reflect increased concerns for the maintenance of forest diversity. However, based on a continuation of historical trends and relationships, forest area in the United States has been projected to decline by an additional 6.5 million *ha* by 2010 (USDA Forest Service 1989).

Table 3. Forest land area (100,000 *ha*) by ecosystem in the United States[1]

Ecosystem	Total	Reserved forest land
Eastern forest:		
White-red-jack Pine	58.7	2.0
Fir-spruce	79.3	2.8
Longleaf-slash pine	63.9	1.2
Loblolly-shortleaf pine	198.7	2.0
Oak-pine	127.9	0.8
Oak-hickory	505.9	10.1
Oak-gum-cypress	119.4	2.8
Elm-ash-cottonwood	61.1	1.2
Maple-beech-birch	193.3	14.6
Aspen-birch	75.3	3.2
Nonstocked	26.3	0.4
Subtotal	1509.8	41.1
Western forest:		
Douglas fir	166.3	24.3
Ponderosa pine	123.8	12.2
Western white pine	1.2	T[2]
Fir-spruce	418.9	34.0
Hemlock-Sitka spruce	77.3	10.5
Larch	10.9	0.4
Lodgepole pine	73.7	16.0
Redwood	5.3	0.8
Other western softwoods	110.1	17.8
Western hardwoods	197.9	15.0
Chapparral	32.8	3.2
Pinyon-juniper	209.6	7.3
Non-stocked	21.9	2.0
Subtotal	1449.7	143.5
United States total	2959.5	184.6

[1]Data from 1987 Resources Planning Act data base (USDA Forest Service 1989); [2]Less than 40,000 *ha*

Mexico

Archaeological evidance points to the interaction between humans and tropical forests that extends far into the past when population densities were actually higher than they are today (Gomez-Pompa & Kaus 1990, Parsons 1975). In Mexico, studies clearly document the existence of ancient civilizations with high population densities integrated within tropical forest ecosystems. Examples are both the Olmec and Maya civilizations of southeastern Mexico that existed in that region for a combined period of at least 3000 *y* (Turner 1976). Population densities in the rural Mayan area today is only about 5 people per km^2 compared to the peak of 400 to 500 people per km^2 during the height of the Olmec and Maya civilizations (Turner 1976). These findings indicate the current extensive areas of tropical forests in Mexico that have been cut over the last 50 *y* were not untouched primeval forest but the result of regeneration since the last cycle of abandonment (Gomez-Pompa & Kaus 1990)

Recent tropical deforestation is associated with a pervasive cycle of initial timber extraction followed by shifting cultivation, land acquisition and subsequent conversion to pasture (Partridge 1984)which leads to loss of forest resources, reduction of biodiversity and impoverishment of rural people (Gomez-Pompa & Kaus 1990). The effect of past civilizations on the structure and composition of today's forests is more than just an intriguing question but is important in determining those practices used by those civilizations to maintain the tropical biodiversity left by previous generations. In fact,one of the primary causes of tropical deforestation in Mexico is due to the neglect of traditional people's vast experience with resource management. The persistence of forest resources and ecosystems following widespread human intervention indicates that a knowledge of management techniques practised by ancient civilizations, such as the Olmec and Maya, could help in reverting current processes of landscape degradation in the tropics (Gomez-Pompa & Kaus 1990)

The first national forest inventory in Mexico lasted 24 *y* (1961-1985). The basic objectives were to locate and quantify forest areas by type, to calculate timber volume in wooded areas and the increment in conifers, as well as to collect ecological and silvicultural information and to evaluate forest condition. Seventy-three percent of the Mexican territory is classified as woodland (144 million *ha*) with 54 million *ha* classified as forest area (Table 4,Cedillo 1990). As in the United States, based on a continuation of historical trends and relationships, forest area is projected to decline by 16.6 million *ha* by 2012 (Table 4)

Table 4. Forest areas (100,000 *ha*) in 1988, 2000 and 2012 by forest type in Mexico[1]

Forest type[2]	1988	2000	2012
Temperate forests:			
Mixed conifer & hardwood	183.0	163.9	146.0
Hardwood	84.4	70.3	57.7
Subtotal	267.4	234.2	203.7
Tropical forests:			
High	19.9	14.7	10.4
Medium	89.0	73.3	58.7
Subtotal	108.9	88.0	69.1
Lower tree forest	170.8	137.2	107.4
Total	547.1	459.4	380.2

[1]Data from Cedillo (1990); [2]Forest types are as described in de Anda *et al.* (1992). Temperate forests include pine and oak with temperate humid and semi-dry climates. Tropical high (with trees > 30 *m* in height) and medium (with trees 15 to 30 *m* in height) forests are found in hot-and sub-humid climates. Lower tree forests have trees 5 to 15 *m* in height and are found in hot semi-dry climates.

Status of forest biodiversity

There is surprisingly little integrative information on the status of forests, particularly as Maini (1992) pointed out that "forests are a rich respository of planet earths' genetic heritage." Forests are usually delineated by the presence of a few dominant species but this barely touches the surface of their species richness. For example, in two pine systems in the southeastern United States, tree species make up less than 10% of the plant and vertebrate animal species (Table 5). And this does not take into account all the thousands of other species likely to be found. May (1992) states, "If we speak of total number of species, then to a good approximation everything is a terrestrial insect." In fact, if one uses an estimate of 3 to 5 million (May 1992) as total species on earth then vascular plants (5.4-13.3%) and vertebrates (0.9-1.5%) only represent 6.3 to 14.8%. These percentages may be off by an order of magnitude if Erwin's (1988) hypothesis of 30 to 50 million species is closer to the true number of species. This illustates the extent of the problem as the approaches to forest management have not incorporated a consideration of the vast majority of species.

Table 5. Species richness in selected forest ecosystems

Taxa	Loblolly[1] shortleaf pine (Texas)	Loblolly[1] slash-pine (Louisiana)
Trees	44	26
Shrubs & Vines	59	66
Grasses	37	49
Forbs	123	156
Ferns	5	8
Amphibians	15	13
Reptiles	23	21
Birds	115	83
Mammals	26	29
Total	447	451

[1]Data summarized from Pearson *et al.* (1987)

Ecological characteristics of forest should be examined in terms of compositional, functional, and structural features (Crow 1989). Forests are much more than simply a collection of varying tree species. There are thousands of vascular plants,vertebrates, and other plant and animal species in any forest type interacting through many processes and pathways. For individuals and populations, these interactions include such mechanisms as predation, competition, paratism, and mutualism, while communities change through the process of succession in response to disturbance phenomena and interact through nutrient and water recycling (Reid & Miller 1989).

Although intensive forest management can simplify ecosystems, other forestry practices can maintain ecosystem integrity (Council of Environmental Quality 1990). Strategies for maintaining complex forest ecosystems include preventing soil erosion, leaving standing dead trees (snags) and fallen trees and leaving living trees as biological legacies. In the Blue Mountains, those plant communities most affected by timber management activities, that is, ponderosa pine and mixed conifer, are also the most productive in terms of wildlife (Thomas 1979). Yet, timber management or other natural disturbance processes maintains the mosaic of successional stages across the landscape. Conserving the biodiversity of temperate forests requires the maintenance of all forest successional stages (Franklin 1988). For example, in the Blue Mountains, as in the forests, the primary forest types have differing mixes of vertebrate species richness from the grass-forb stage to old growth condition (Table 6).

Alterations in forest structure can effect the conditions necessary for the survival of many species. Clearcuts within a forest create open areas that change temperature and moisture regimes ana reauce tne amount ot cover (Council of Environmental Quality 1990). Fragmentation also exposes the interiors of the remaining patches to both external physical and biological factors that enhance the conditions for some species but decrease them for others. In a larger spatial context of a landscape, species diversity is usually reduced, not increased, by fragmentation. Species adapted to conditions in the interior of large contiguous forest patches are often lost as patch sizes are reduced and the numbers of openings increased.

Table 6. Number of vertebrate species associated with each successional stage for reproduction and feeding in the Blue Mountains of Washington and Oregon[1]

Plant community	Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
Western juniper:						
Reproduction	50	62	52	61	66	64
Feeding	100	104	82	83	86	86
Deciduous riparian:						
Reproduction	93	107	93	108	121	-
Feeding	182	188	150	151	161	-
Quaking aspen:						
Reproduction	28	58	59	65	68	-
Feeding	104	125	110	109	116	-
Ponderosa pine:						
Reproduction	45	58	56	71	95	91
Feeding	120	129	114	119	135	137
Mixed conifers:						
Reproduction	32	57	65	84	115	108
Feeding	99	114	112	122	136	132
White fir:						
Reproduction	24	35	44	62	82	77
Feeding	68	80	82	91	101	100
Overall:						
Reproduction	164	174	147	171	209	174
Feeding	253	249	191	200	215	192

[1]Data summarized from Thomas (1979)

Much of the concern for biodiversity stems from the increasing evidence for growing losses of species (Wilson & Peter 1988, McNeely *et al.* 1990, Global Biodiversity Strategy 1992,). Habitat loss, degradation, and fragmentation are the most important influences upon species extinction rates (Reid & Miller 1989). Human impacts on the environment do not threaten all groups of species equally with those at greatest risk having small population sizes, varying greatly in population size, or having slow rates of population growth (Reid & Miller 1989). Species richness of vascular plants and vertebrates in Canada, United States and Mexico generally increases along a north to south gradient (Table 7). Although threatened plants and vertebrates represent only a small portion of all species found in North America, they do indicate the magnitude of the problem (Table 8). However, generalizations about the status of threatened plants and vertebrates in the three countries must be viewed with caution as the intensity of effort on the listing of rare and threatened species is much greater in the United States. As of 1990, 1.8% of all vertebrate species recorded in the United States since European settlement have gone extinct or are presumed extinct and 10.5% are either critically imperiled or imperiled (Table 9). The situation is probably more severe in other groups if cray fishes (36% extinct, critically imperiled or imperiled) and unionid mussels (55% extinct, critically imperiled or imperiled) indicate potential extinction in vertebrates (Master 1990).

Table 7. Species richness of higher plants and vertebrates in North America

Taxa	Canada	United States	Mexico
Flowering Plants	2920[1]	18,956[1]	20,000-30,000[1]
Gymnosperms	33[1]	113[1]	71[1]
Ferns	65[1]	404[1]	1000[1]
Mammals	197[2]	466[2]	439[2]
Birds	426[2]	1090[2]	961[2]
Reptiles	42[2]	368[2]	717[2]
Amphibians	41[2]	222[2]	284[2]
Fish (fresh & saltwater)	1132[2]	2640[2]	?

[1]Data from Groombridge (1992); [2]Data from World Resources Instiute (1992); U.S. numbers include Pacific and Caribbean islands

Table 8. Threatened plants and vertebrates of North America by country [1]

Taxa	Canada	United States	Mexico
Plants	13	2476	1111
Mammals	5	21	26
Birds	6	43	35
Reptiles	0	25	16
Amphibians	0	22	4
Fish	15	164	98
Total	39	2751	1290

[1]Data from World Resources Insitute (1992)

Table 9. Status of selected animal groups in the United States [1]

Species Rank	Mammals	Birds	Reptiles	Amphibians	Fishes	Crayfishes	Uniod mussels
Extinct (GX & GH)	1	22	0	4	19	3	29
Critically imperiled (G1)	8	25	6	23	78	62	88
Imperiled (G2)	23	9	10	17	72	49	49
Rare (G3)	19	23	25	26	110	84	35
Secure or abundant (G4-G5)	330	628	251	153	549	106	73
Not yet ranked (G?)	62	55	9	3	24	9	26
Total	443	762	301	226	852	313	300

[1] Data from Master (1990); Ranks are those used by the Natural Heritage Network's central zoological databases

Inventory and assessment

Current national forest inventories in North America as in most of the world use inventory procedures that suffer from two weaknesses when applied to the broad issue of biodiversity. First, both are largely driven by the need to obtain information demanded by public and industrial planners for commercially important species, especially timber. Second, the inventories are usually limited in scope to one time of year (often spaced many years apart) and for vegetation only. Better inventories and assessement are needed of current conditions, abundances, distributions and management direction for genetic resources, species populations, biological communities and ecological systems. Inventory and monitoring efforts will have to be expanded to include more than just dominant tree species. The broadening of forest objectives will require additional ecological information, particularly for tree species that have received little management attention and also for other woody and herbaceous vegetation in the understory (Harrington *et al.* 1990). In fact the UNEP/FAO Joint Working Party on Forest Economics and Statistics in a survey done for their Follow-Up to the 1990 Assessment found that one of the items that attracted the strongest support for inclusion in the 2000 Forest Resource Assessment was the "quantification of the environmental and other non-wood benefits of the forest". The recently negotiated Global Convention on Biological Diversity has a section on identification and monitoring that provides some guidance on the types of information needed for the conservation and sustainable use of biodiversity. Specifically this is given in Article 7 and Annex I:

Article 7. Identification and monitoring

1. Identify components of biological diversity important for its conservation and sustainable use having regard to the indicative list of categories set down in Annex I;
2. Monitor through sampling and other techniques, the components of biological diversity identified pursuant to subparagraph (a) above, paying

particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use;

3. Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques; and
4. Maintain and organize by any mechanism data derived from identification and monitoring activities pursuant to subparagraphs (a),(b), and (c) above.

Annex I. Identification and monitoring

1. Ecosystem and habitats; containing high diversity, large numbers of endemic or threatened species, or wilderness; required by migratory species; of social economic, cultural or scientific importance; or which are representative, unique or assosiated with key evolutionary or other biological processes;
2. Species and communities which are: threatened, wild relatives of domesticated or cultivated species; of medicinal, agricultural or other economic value; or social, scientific or cultural importance; or importance for research into the conservation and sustainable use of biological diversity, such as indicator species; and
3. Described genomes and genes of social, scientific or economic importance.

The United Nations Environment Programme (UNEP) has provided suggestions for elements in future forest assessment dealing with biodiversity. These include forest types, dominant species, human impacts on forests and reliable species identification. UNEP also recommended that the distribution of forest types and changes due to human impact needs to be monitered regularly but that species level information is not possible in the global forest assessment. This is consistent with growing scientific sentiment that biodiversity should be dealt with at the scale of habitats or ecosystems rather than species (Hunter *et al.* 1988). However, how to deal with this technically is still in the developmental stages in most cases and could lead to unfortunate circumstances where is it not possible to go back and reanalyze the data using other criteria particularly if community and ecosystem characterics are not available.

Moreover, spatial scale be it local, regional, or global, greatly influences our perceptions of biodiversity (Crow 1989). Understanding the importance of scale is critical to accurately assessing the impact of land management practices on biodiversity. For example,a strategy to maximize species diversity at the local level does not necessarily add to regional diversity. In fact, oftentimes in our haste to "enhance" habitats for wildlife we have emphasized "edge" preferring species at the expense of "area" sensitive ones and consequently may have even decreased regional diversity. It is important to realize that principles that apply at smaller scale of time and space do not necessarily apply to longer periods and larger spatial scales (Crow 1989).

Yet, it is almost a mind-boggling task to contemplate the development of an integrated, concise and relevant approach to the inventory and assessment of forest biodiversity. There are considerable obstacles to coordination and compatibility. Technical problems include: 1) choosing an appropriate classification system, 2) determining the appropriate spatial scale; and 3) organizing the resulting data and information in a useable and retrievable database. While compatibility and comparability of methodology and data management may be best accomplished at the international level, surveys and inventories are more appropriately conducted at a regional or national level, since they allow a nation to determine the extent and degree of endangerment of its biological resources (U.S. Proposal for an Interim Biodiversity Survey, Inventory and Data Organization Plan, 1992). However,there are some broad principles recommended in the Keystone Report (1991) on "Biodiversity On Federal Lands" that provide some insights for the development of national level inventory and assessment programme. These include:

- The inventory should be hierarchical and "top-down" in the sense that landscape level assessments such as the U.S. Fish and Wildlife Service's "gap analysis" are used to identify priorities for inventory at the local level, and local assessments are used to identify priorities at the site level;
- The inventory should make maximum use of existing data management systems;
- The inventory should be landscape based in the sense that abundance and distribution of plant and animal species are correlated with soils, vegetation, plant and animal community characteristics, and landscape features;
- The inventory at a minimum should include natural vegetation, all vertebrate and vascular plant species and at least some indicator species of non-vascular plants and invertebrates, and some indicators of other elements of biodiversity, such as sensitive communities or human- influenced processes and elements of structural diversity;
- Provision should be made for systematic inventories of all candidate, threat ened, endangered, and sensitive species and for all other elements that are imperiled due to human activities or natural events;
- Inventories should be guided by an inter-agency master plan that coordinates acquisitions of aerial photography, soil survey, vegetation survey, and vertebrate inventory that ensures compability of data within and among agencies;
- The above mentioned master plan should be implemented for all regional ecosystems and vegetation mapping and inventory of vertebrates should be completed within the next ten years;
- The inventory should be compatible with, and feed information directly into, development and implementation of Geographic Information System (GIS) methodology, monitoring programmes and research activities;
- The inventory should provide the basis for determining species (including genetic level assessment), species groups, population guilds, habitats, landscapes or processes that require more intensive studies;

- Inventories should be coordinated with and make maximum use of the fifty state Heritage Programme data bases, procedures and technology;
- The inventory process should identify levels or intensities of inventory that are appropriate for each level of planning, type of management activity or impact, type of land classification or degree of rarity or sensitivity of the element being inventoried;
- The inventory should have a strong element of quality control and assurance, including setting specific standards of accuracy and precision, timing the inventory to encompass the life-cycles of the target elements, standardizing methods and databases to the extent possible, and using trained personnel to conduct the inventories.

However, even on an area the size and geographic scope of a Typical National Forest in the United States, native biodiversity can easily encompass thousands of species plants and animals, dozens to hundreds of identifiable biological communities and an incomprehensible number of pathways, processes, and cycles through which all that life is interconnected. Obviously, it is not possible to address each and every aspect of this complexity. Therefore, identification is of specific aspects of diversity, such as distinct species, biological communities, or ecological processes that warrant special consideration (Salwasser 1990).

The need for more specific data and more efficient ways for collecting and managing data should lead to significant changes in the inventory process. Changes to be evaluated include use of methods and technology that will: (1) provide resource estimates for specific geographic units and evaluate the reliability of such estimates; (2) display estimates and units spatially; (3) make maximum use of existing information and new technology, such as remote sensing and geographic information systems; (4) provide a baseline for monitoring changes in the extent and condition of the resource; (5) eliminate redundant data collection, develop common terminology and promote data sharing through corporate data bases; (6) utilize information management systems to provide maximum flexibility for data integration, manipulation sharing, and responding to routine and special requests; and (7) provide up-to-date bases using modeling techniques, accounting procedures, and re-inventories.

The advent of geographic information systems (GIS) holds future promise for the development of a comprehensive biological information system (Davis *et al.* 1990). Much work and coordination will be involved to bring this to pass. There will be a constant need to continually check and update the databases. It is not enough to set up the system and then use it without regard to the dynamics of ecological systems.

One promising approach is the "Gap Analysis Programme " headed by the United States Fish and Wildlife Service (Scott *et al.*1987,1990,1991 a & b). This programme links wildlife diversity to habitat characteristics using species range maps and vegetation maps. Gap analysis is generally being developed by states and the data are intended to be eventually merged for analysis by ecoregion. Gap Analysis is a tool to help maintain biodiversity. It uses computers to map the distribution of plants, terrestial vertebrates, endangered and candidate species and other indicator species; to identify areas of high species richness and ranges of endangered or unique species; to compare these with land use practices and protected areas; and to identify gaps in the protection of biodiversity. Instead of focusing only on individual species,Gap Analysis allows resource managers to examine the big picture and to develop comprehensive plans which simultaneously address several species in their ecosystem context. This results in cost efficiency by avoiding redundancy and duplication in management activities. This tool has received widespeard attention and support within the United States and more recently, other nations (United Kingdom, Germany,Australia and Mexico) have also expressed interest in conducting a Gap Analysis within their borders.

Monitoring

The inventory and assessment of forest ecosystems is only the first step in the evaluation process. Changes monitored over time allows us to assess the consequences of management practices. It is essential in an adaptive management strategy that one be capable of monitoring critical indicators of diversity, particularly those related to management objectives and those variables that can be used to explain behavior and predict future trends. Monitoring obviously has the potential of being very costly and the demand overwhelming. Some methods of setting monitoring assistance priorities is needed. Our present concepts of monitoring vary depending on who is expressing them, their background and the objectives of the monitoring being discussed. There is a need for greater coordination,with considerable direction and standardization set at both National and Regional Levels. Monitoring means different things to different people. Just what it is depends solely on monitoring objectives.

Monitoring should provide sufficient information about the abundance of animals or plants targeted for monitoring to assure that current management practices are not threatening the long-term viability of their populations (Verner 1986). But, monitoring efforts are often severely hampered by the lack of prior planning and thought given to the desired results from any given monitoring effort. It is not enough to select a management indicator species,guild, or other monitoring target with the idea that this will allow us to assess the impact of any given management activity (Szaro & Balda 1982, Szaro 1986,Tilghman & Verner 1989). Ideally, the results from monitoring should feed back into the system to correct or fine tune management activities.

Effort should not be wasted on a monitoring system that fails to give the level of confidence needed by policy makers and managers to deduce the most likely effects of management activities on forest resources. In an era when mankind's activities are the dominant force influencing biological communities, proper management requires understanding of pattern and process in biological systems and the development of assessment and evaluation procedures that assure protection of biological resources (Karr 1987). It is essential to strive for appraisals of these resources that give us the ability to forecast the consequences of human-induced enviromental changes accurately (Hoekstra & Flather 1986). But we have a long way to go in this process.

First there has to be clear understanding of goals and objectives. The next step is to assess risk and assign priorities. The critical step is to formulate the type of questions that need to be answered to determine that we are meeting our goals and objectives. It is absolutely critical to ask the right question in the first place. It will be necessary to perform a kind of environmental triage in order to determine when enough is enough. With limited financial and physical resources it may become necessary to make the highly undesirable decision to no longer try to prevent the extinction of particular species.

Monitoring should also have a strong element of quality control and assurance, including setting specific levels of accuracy and precision, timing the inventory to encompass the life cycles of the target species, as much as possible, and standardizing methods and databases for all organizational units, especially when monitoring the same species. However, whatever is done must be as cost-effective as possible. Some possibilities are risk analysis, increasing the scope of monitoring efforts, and determining the needs of monitoring objectives. Monitoring might be limited to direct monitoring for only high risk species or habitats, on a priority basis, while relying on habitat relationships for most other species. Monitoring efforts should be spread over as large a geographical base as possible (and feasible) to reduce the cost per unit area and to increase the scope of applicability. Whenever possible, monitoring should only be asked to detect declining trends because of the potential cost savings (almost 90%) (Verner 1986).

Along with this is our need to develop a quality control and assurance programme that ensures: (1) objectives are measurable (and thus monitorable); (2) appriopriate measurement techniques and procedures are being used; and (3) management thresholds are clearly identified and incorporated into the planning process so that, if crossed, they automatically trigger a reanalysis of planned activities.

The quantitative aspects of monitoring impose problems in quality control and assurance that seem particularly perplexing. The first,and most obvious, is statistical validity or in other words quality control. Any time quantative data is collected, its validity is a potential issue. Observer, seasonal, or annual variability all contribute to potential sources of bias or error. Monitoring systems must be developed that allow for differences or at least control of these sources of error. It is also important that the protocols are rigidly followed once the monitoring process has started. Monitoring protocols CANNOT be subject to whimsical changes in order to ensure the integrity of the data. Once started there are only two options: (1) continue the monitoring plans, or (2) end the monitoring when our needs are met. Any other option invalidates monitoring efforts and WASTES all prior data and the expenditures involved in the collection of those data. It is highly desirable if at least regionally monitoring plans for the same species in the habitats be consistent.

The second problem area is that of quality assurance. This is in some respect similar to the statistical problems just mentioned. There is enough difference, however, that it needs some recognition on its own. Quality assurance is a process whereby data quality is defined, not a process that forces data to meet a particular standard. The data quality needs to be sufficient to meet the purposes defined for its collection. Quality assurance is simply a process of establishing and documenting what that quality is. Quality assurance deals with such concepts as precision, accuracy, comparability, representativeness, and completeness of the data. Environmental issues seem to be ever more contentious in the public arena. This trend is likely to make data quality assurance much more important in the future.

What to measure? That depends on objectives and concerns - alternatives include the presence or absence of a species across the landscape, measures of change in diversity, species richness, genetic variability, a whole litany of possibilities [see Magurran (1988) for a good discussion of measuring ecological diversity]. Biodiversity is NOT a single entity with the possibilities of us deriving a simple index of increasing or decreasing biodiversity (Salwasser 1990). Where to measure? This depends on the scale and scope of the assessment or inventory but should be determined in view of context considerations. How and when to measure? These are technical questions that will require extensive planning and statistical analyses.

Restoration, rehabilition, and reforestation in the United States

Ecosystem restoration does not always require intervention. Left to natural processes, many ecosystems will return to something like their pre-disturbance conditions if populations of original species still exist nearby (Reid & Miller 1989). For example, a temperate climate and productive soils promote natural re-establishment of forests in regions of United States. However, restoration technologies can speed the recovery of communities and ecosystem after disturbance and can enhance *in situ* conservation (Reid & Miller 1989).

The area of United States forests that should be classified as degraded is not clear; deforestation (as generally understood in the international context) is not a serious concern in the United States. Nonstocked and understocked forests exist in most regions, but account for relatively little of the total forest land in any region (less than 5 %) (Table 2). Market forces encourage industrial owners to maximize productivity of managed lands, and therefore minimize or eliminate underproductive land. The majority of nonproductive forest land in the United States is owned and managed by non-industrial private owners. Technical and financial barriers may limit the ability of these owners to improve productivity of these forests. However, programmes funded by federal and state resources target this problem.

Forest trees are currently planted or seeded on roughly 1.2 million *ha* in the United States each year (Mangold *et al.* 1992). This includes reforestation following harvest, as well as afforestion of land formerly used for crop or livestock production. Planting and seedling has averaged more than 500,000 $ha\ y^{-1}$ for more than 60 *y*; in the last decade, tree planting averaged more than one million hectares per year. Most planting is used to control species composition (to favor commercially valuable species) and to improve productivity.

Sustainable use and development

The question of sustainability varies between temperate and tropical forests. According to the World Commission on Environment and Development, sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs. This view actually parallels ecosystem dynamics as their very nature are in a constant state of flux, always shifting and changing from one condition to the next, and true steady state probably never exists (Heede 1985). Yet, even though forests are resilient ecosystems, there are limits to their ability to withstand perturbations before they start to degrade (Maini 1992).

The sustainability and stability of ecosystems should not be judged solely upon constancy of species composition (Waide 1988), especially since managing for single species or group of similar species is often criticized as contrary to the goal of biodiversity conservation because it can eventually lead to ecosystem simplification (Wilson & Peter 1988). But even the sustainable use of single species requires the maintenance of a minimum level of genetic diversity to maintain viability and adaptive fitness and must also allow for a large scale demographic balance between local extinction and dispersal to maintain viable populations (Waide 1988). Recent responses to current environmental concerns about mass extinctions of many species and varieties due to population related pressures on land and water resources has translated into an effort to effectively conserve whole communities or species assemblages.

Biological, spatial and temporal diversity are clearly central determinants of long-term sustainability at local to global scales (Cook *et al.* 1991). The loss of diversity has been suggested as a factor in the destabilization of ecosystems which then increases their sensitivity to stress and disturbance (Robinson 1988). The structure and arrangement of diverse elements are crucial at all scales since natural ecosystems are arranged as mosaics (Pickett & White 1985, Cook *et al.*). However, ecosystem stability is not necessarily or uniquely related to the species persistence or the constancy of species composition over time or space (Waide 1988). At a certain level, species diversity represents a funtional redundancy at the ecosystem level with macroscopic ecosystem properties being insensitive to some range of species composition (Waide 1988). Morever, change *per se* is not necessarily something to be avoided. It ultimately may be the underlying motivating factor in management decisions. For example, vegetation structure or composition can be altered to emphasize rarer or endangered species. The concepts of sustainability and ecosystem stability are clearly linked and must be melded in any effort (Waide 1988).

Reducing demands on forest resources

Plantations

The potential role of forest plantations in supplying future demands for timber products will be determined by the balance struck in policy decisions responding to increasing demand for forest products and public pressure for an environmentally sensitive manner of land management. Intensively managed forest plantations may help alleviate pressure on other more sensitive forest ecosystems by meeting demands on a smaller proportion of the overall landbase and thereby allowing more natural areas to be set aside and left alone (USDA Forest Service 1990). The experience in the United States with plantation forests, similar to that of other developed countries, is that plantations are an effective and efficient production method to support an industrial forest economy.

Based on the success of forest plantations increasing attention is being paid to possible (negative) ecological consequences of plantation programmes. Forest management techniques in general, and forest plantations in particular, have been criticized for emphasizing single species (monoculture) in place of the mixed species that are more characteristic of native forests. Yet, most species planted are native with a considerable variety in genetic material in the hopes of minimizing susceptibility to insects and diseases and maintaining the stability or integrity of regional forest ecosystems. Biological and structural simplication, although obvious objectives for efficient production, are sources of concern when they are widespread. There is increasing recognition of the impacts of plantation management on non-timber components of forests (especially wildlife). These concerns are legitimate, but attention to the possible negative consequences of plantation management can be minimized when used as part of an overall landscape approach to conserving biodiversity.

Promotion of efficient use of forest resources in temperate forests

More efficient use of forest resources is another way of potentially alleviating the pressure on forest ecosystems. Utilization research has led to the more efficient use of wood in temperate forests. Major developments in the past 30y have been the substitution of softwood lumber in many applications, substitution of fibre based panels for softwood plywood, pulping of hardwood species, and development of laminated beams. Utilization has progressed to the point where almost all wood taken from logging sites is used, and the volume left at logging sites has been declining.

Promotion of efficient use of forest resources in tropical forests

In contrast with utilization in temperate forests, strategies for the efficient utilization of tropical forests are not as well developed. Presently, the diversity of species and sizes of trees in tropical forests result in low net utilization of the available resource. In part, the low utilization results from the costs of handling mixed sizes of logs. More frequently, few logs are selected because only certain species are marketable or, in other situations, select species yield an enormous premium to the balance of the logs on the site. The result is an extensive search through the forest for the premium logs of the most merchantable species. The outcome is the harvest of a few boles per hectare spread over a far reaching area. Providing road access to large reaches of the forest in pursuit of a few species allows colonisation of a much greater area of the area of forest than if more wood demands could be met from a smaller area.

Two complementary strategies must be promoted to combat extensive harvest of a few logs per hectare. First, better understanding of the wood-working properties of many tropical species could make possible better use of the wood on sites logged. Second, emphasis must be placed on meeting the demand for industrial wood through the use of scientific principles in forest plantations. Tremendous gains in wood output per hectare are possible in some tropical climates. Equally important, well-crafted plantation programmes provide a wood fibre tailored to meet particular industrial processes. Thoughtful plantation programmes can offset harvest on thousands of hectares of tropical forests which have not yet been entered. It is useful to note that the private sector is very successful in establishing and sustaining plantation forests. World wide, these plantation forests are meeting larger and larger percentage of the needs of wood processing facilities in the private sector.

Recycling

Not only can recycling help to curb growing demands for wood products but it can also reduce demands for waste disposal sites. For example, the United States does not have in place recycling programmes for solid wood products and is running out of acceptable sites for landfilling municipal solid wastes. Over 40% of these wastes, by weight, consists of forest products. Where the United States once had 18,000 landfills, it is now down to 6000. Projections of waste volume and landfill capacity for the year 2000 suggest there will be a shortage of space for 54 million tons of solid waste.

Recycling can make substaintial gains in decreasing demands for resources by:

- Enhancing paper recycling technology; including separating paper and wood waste from the municipal waste stream, fibre cleaning, fibre sorting technologies, bond strength restoration, fundamental structural transformations of fibres, utilization and new bleaching technologies;
- Developing alternative technologies for using recycled paper and wood wastes to produce fibre-plastics composites, wet-formed structural fibre products, inorganic-bonded wood composities, fibre mats from recycled wood fibre, and using wood pallets and demolition waste for fuel;
- Providing on-going economic evaluation of new technologies. Evaluations will be used to help focus development activities on economically feasible products and processes.

Research needs

Our understanding of biodiversity is often surprisingly superficial and we have hardly begun to appreciate the extraordinary complexity of forest ecosystem (Soule & Kohm 1989). Several recent efforts have examined research needs for biodiversity (Global Biodiversity Strategy 1992, Lubchenco *et al.* 1991, Reid & Miller 1989, Solbrig 1991, Soule & Kohm 1989). There is a large degree of overlap in all these efforts but the focus and scope of the effort depend on the perceived needs of the individuals and groups involved.

Soule and Kohm (1989) identified the following most pressing and important initiatives and research needs:

- A crash programme to carry out extensive surveys and mapping to identify critical areas for protection;
- A coordinated research programme at selected sites in the tropics for comparative research on populations,communities, and ecosystems in relatively undisturbed and secure situations;
- Enhanced support for research on fundamental species level processes, such as physiology, reproduction, behaviour and viability of individuals, especially with regard to species of critical ecological or economic importance;
- Studies at all spatial scales to assess the kinds, mechanisms and magnitudes of impacts on ecological systems; and
- Training for scientists and natural resource managers, particularly in tropical developing countries.

These same themes were identified in most other assessments of research priorities. Reid and Miller (1989) added a critical component to "Integrate the study of cultural diversity into biodiversity research". Solbrig (1991) took a hierarchial approach by looking at many detailed hypotheses at varying levels of organization from genes to ecosystems. One additional component identified in the later effort not in the prior two, was the inclusion of monitoring and how it should be done and the role it should play in future international programmes. Lubchenco *et al.* (1991) in the Sustainable Biosphere Initiative had three broad research recommendations but stressed a new integrated programme of research on the sustainability of ecological systems that should focus on understanding the underlying ecological processes in natural and human-dominated ecosystems.

The importance of involving the human component in any research agenda was stressed by the two of the four research action items in the Global Biodiversity Strategy (1992):

- Action 81: Strengthen social science research on the connections between biological and social processes;
- Action 82: Strengthen research on ethical, cultural and religious concerns related to conserving biodiversity.

One critical problem in these efforts is the perception by managers that scientists are often too distant from management issues to effectively focus research on critical information needs. Working with land-managers, USDA Forest Service Research (Szaro unpublished) identified six critical biodiversity research questions of programme emphasis to provide the tools and information needed to support management goals:

- How do we integrate resource uses and ecological values across a range of spatial and temporal scales?
- How can we protect, maintain and enhance biodiversity and productivity while managing resources for human uses?
- How do we account for and respond to societal needs and economic considerations?
- What can we use as measurable indicators for monitoring changes in biodiversity?
- How can networks of reserved areas, buffer zones and high use areas be effectively intermixed across the landscape to maintain biodiversity?
- How can we maintain those native species whose range and populations are threatened by introduced insects, diseases and other exotic organisms?

Then role of science in the conservation of biodiversity is critical. More research to improve methodologies, distributional and status information, and strategies based on sound information will ultimately provide the basis for all sound policy and management decisions.

Future options

The protection and maintenance of biodiversity is a long-term issue, which will create problems in political systems that deal primarily with the short-term goals and objectives. The most obvious conflicts will be political and financial. There are inherent biases in a market economy that tend to result in environment degradation. The enviromental costs are generally passed to the public at large. Attempts to internalize such costs are resisted strongly by private industry. For example, installation of scrubbers in smokestacks and catalytic converters on cars in the United States were not welcomed by industry. Similar results are likely in actions to protect biodiversity. The Tellico Dam in the United States was chosen over possible extinction of a small fish, the snail darter. Today the timber industry is against setting aside old growth forests on the basis of the impacts on local jobs and economies. The actual monetary costs may not be as large as the political costs. For every action taken, there will be winners and losers. The loss of diversity will have long-term effects as we lose what are essentially building blocks for human survival. Using a financial analogy, we should manage our biological resources so that we can live off the interest. Living off the principal eventually leads to bankruptcy.

Implementing biodiversity goals will require resources and knowledge. Current scientific understanding of ecological processes is far from perfect.

Existing resources could be real located, but additional resources will be necessary for improving efforts in inventory, monitoring and basic research.

Understanding the importance of scale is critical to accurately assessing the impacts of land management practices on biodiversity (Crow 1989). Many significant biological responses and cumulative management effects develop at the landscape level. Planners and managers are increasingly aware that adequate decisions cannot be made solely at the stand level, particularly when land use patterns characteristic of human dominated landscape are ones in which large, continuous tracts of natural habitat become increasingly fragmented and isolated by a network of developed lands. Thus, regardless of what the primary management objective may be, be it producing timber, creating wildlife habitat, protecting watersheds, or providing wilderness experiences, assessing these opportunities clearly requires consideration beyond the boundaries of a particular planning unit.

Change has profound implications for land management. Historically, the quest for stability and preventing change in areas where productivity was maintained by dynamic events has led to the declining quality and quantity of many of our most desired habitats. Much prior management of habitats has viewed systems as being immutable and all that is necessary is to put a fence around an area and we will save it forever. However, this is simply not the case. Ecosystems by their very nature are in a constant state of flux. The effects of land management decisions must be evaluated using ecologically relevant time scales as well as spatial scales (Brooks & Grant 1992). This is a constant challenge to land managers. Changes resulting from periodic, abrupt, and/or catastropic environmental factors, lead to displacement, replacement, and succession with species composition tied to the frequency and types of disturbance. Change *per se* is not necessarily something to be avoided. It ultimately may be the underlying motivating factor in management decisions. We may wish to alter vegetation structure or composition to emphasize rarer or endangered species.

Shifts in climatic patterns whether naturally occuring or caused by man-related activities are in the news constantly. Certainly long-term shifts have had profound effects on species distribution but over a sufficient time frame to allow for adjustments. For example, paleobotanical records of the eastern United States indicate major northward range extensions of many southern tree species and the more northward movement of others. Yet, human induced climatic swings are likely to occur over a scale of a few decades, rather than thousands of years, giving little time for these natural adjustments.

Threatened and endangered species have long been the focus of biodiversity concerns at the level of plant and animal species, but they represent only one aspect of a larger issue: conservation of the full variety of life, from genetic variation in species populations to the richness of ecosystems in the biosphere(Salwasser 1990). The best way to minimize species loss is to maintain the integrity of ecosystem function. The important questions therefore concern the kinds of biodiversity that are significant to ecosystem functioning. To best focus our efforts we need to establish how much (or how little) redundancy there is in the biological composition of ecosystems. Functional groups with little or no redundancy warrant priority conservation effort (Walker 1992). It is axiomatic that conservation of biodiversity cannot succeed through "crisis management" of an ever expanding number of endangered species. The best time to restore or sustain a species or ecosystem is when it is still common. And for certain species and biological communities, the pressing concern is perpetuation or enhancement of the genetic variation that provides for long-term productivity, resistance to stress, and adaptability to change. A biologically diverse forest holds a greater variety of potential resource options for a longer period of time than a less diverse forest. It is more likely to be able to respond to environmental stresses and adapt to a rapidly changing climate. And it may be far less costly in the long run to sustain a rich variety of species and biological communities operating under largely natural ecological processes than to resort to the heroic efforts now being employed to recover California condors (*Gymnogypes californianus*), peregrine falcons (*Falco peregrinus*), and grizzly bears (*Ursus horribilis*). Resource managers know from experience that access to resources is greater and less costly when forests and rangelands are sufficiently healthy and diverse.

The tough choices posed in the spotted owl (*Strix occidentalis*) case in the Pacific Northwest of the United States typify many future issues as the conservation of forest biodiversity becomes a higher social priority. Regardless of the eventual outcome of this issue, there is an important lesson to be learned: Conserving biodiversity will not be cheap or noncontroversial. Federal land management agencies in the United States have increasingly come under fire over management decisions that appear to decrease biodiversity. The USDA Forest Service faces numerous appeals and lawsuits on the forest plans for insufficient and sometimes conflicting consideration of forest biodiversity in management decisions. The dispute over the spotted owl and old growth forests is the most visible example of how tough it is to blend the conservation of biodiversity with other uses and values of public resources. It illustrates the reality of "no free lunch" in resource allocations. Even though parks, reserves, set-asides, and easements are critical components in the mix for the conservation of biodiversity they will become more difficult to come by and ultimately will require an expansion beyond the "reserve mentality" (Brussard *et al.* 1992). Multiple-use of public lands is deeply ingrained. Somehow we have to come up with management prescriptions for our public lands that will allow both consumptive and nonconsumptive uses but will do so in such a way that no net loss of native species will occur. Such a prescription will require that the livestock, timber and mining industries take their turns at the trough instead of always going to the head of the line. This will require encouraging resource conservation and recycling programmes that reduce the need for raw materials from public lands (Brussard *et al.* 1992).

Ecosystem level management is going to require new approaches in planning, monitoring, coordination and administration. A new paradigm is needed, one that balances all uses in the management process and looks beyond the immediate benefits. Future conservation at larger scales will always be confounded by the potentially large number of political authorities that conduct land management practices on watershed,basin or even landscape scales. Biodiversity cannot be managed in isolation from political and social realities. Population growth and its resulting impact on resource demands is the most important factor in the fate of forest biodiversity. Thus, maintaining the integrity of the remaining natural ecosystems is closely linked with resource and social issues.

The potential effects of a diversity mandate on other resource uses must be viewed from both a short- and long-term perspective. Conserving biodiversity involves restoring, protecting, conserving or enhancing the variety of life in an area so that the abundances and distributions of species and communities provide for continued existence and normal ecological functioning, including adaptation and extinction. This does not mean all things must occur in all areas, but that all things must be cared for at some appropriate geographic scale. People must be challenged to "think big" - to expand their thinking from individual timber sales, grazing allotments, and single species management over short time frames to conservation of multiple species, metapopulations, ecosystems and landscapes over long time spans (Brussard *et al.* 1992). Maintaining biodiversity requires attention to a wider array of components and larger landscape units in determining management options. There will be trade-offs, commodity production may decline in the short term, but in the long term these trade-offs will result in gains in sustained productivity while maintaining biodiversity with its complete range of ecological processes.

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